A STEPPED PARABOLIC ANTENNA FOR AN S-BAND RADAR ALTIMETER

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ABSTRACT

A compact, light-weight antenna, for use with a radar altimeter system, has been developed for aerial survey work over tropical rain forest terrain. The device incorporates a stepped parabolic reflector with a standard S-band waveguide feed. Notes concerning the application, fabrication, and tests to determine electrical performance, are presented.

RÉSUMÉ

Une antenne compacte et légère, qui sera utilisée avec un système de radar altimétrique, a été mise au point en vue de travaux aériens de levés de terrain au-dessus des régions de forêts tropicales. Le dispositif comporte un réflecteur parabolique à échelons et une alimentation standard par guide d'ondes fonctionnant dans la bande S. Des notes sont présentées au sujet des applications et de la fabrication du dispositf, ainsi que des essais permettant de déterminer son rendement électrique.

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INTRODUCTION

General

Les Consultants Plurifor Inc. of Sillery, Quebec, is a consulting firm whose activities include aerial photographic surveys of forests in order to determine timber content. In Canada, average foliage conditions are such that a two-camera system mounted on a helicopter is capable of seeing through the leaves to the ground, thereby yielding adequate data.

A current contract, in conjunction with the Canadian International Development Agency (CIDA), involves flights over the Columbian tropical rain forests. Foliage density is such that the forest floor is virtually blocked to the cameras lens. It is essential, however, that the height of the helicopter above the forest floor be known. This requirement made it necessary to employ, in addition to the cameras, a radar altimeter system capable of foliage penetration. Typical helicopter instrumentation will be similar to that shown in Fig. 1.

Following discussions, arranged by International Relations (NRC), with Les Consultants Plurifor Inc. and F.P. Radars (1,2), it was agreed that the latter would provide a design and that the Division of Electrical Engineering, NRCC, would build, adjust, and test the two required antennas.

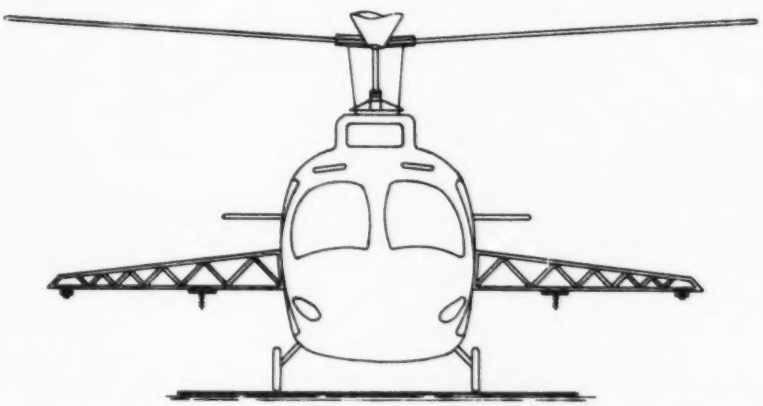


Figure 1 Helicopter mounting arrangement showing outboard cameras and inboard antennas

* F.P. Radars Ltd., Prescott, Ontario

This report includes details of
- parabola and feed design and construction
- antenna focussing and pattern measurements
- impedance matching

A complete account of laboratory procedures is not included; however, equipment block diagrams and some brief notes have been prepared to aid in the interpretation of the test data.

Antennas

Since the two identical antennas were to be mounted beneath a helicopter, compact size was an essential factor to satisfy limited clearances between the fuselage and the ground. A normal parabolic reflector would have resulted in excessive diameter and focal length. Design drawings called for a 20.5-in. (52-cm) diameter, 3-in. (7.6-cm) thick single-step parabola, fed with an "S"-band double dipole waveguide feed. The completed feed extended 3 in. (7.6 cm) behind the reflector and 8 in. (20 cm) out from the front surface. Unit weight was about 6.3 lb (2.9 kg). See Figs. 2 and 3.

CONSTRUCTION

Parabolas

The main body of the dish is composed of 3-in. (7.6-cm) thick styrofoam SM, Blue Type IV - a high density, closed cell polystyrene foam - a Dow product which conforms to CMHC Specification No. 6525. This material has the following general characteristics (3):

- light weight
- very low water absorption
- high compressive strength
- does not sustain mold growth
- has no food value for rodents or vermin
- is combustible but contains a flame retardant additive to inhibit accidental ignition from small fire sources
- good resistance to brine, asphalt, acids, bases
- poor resistance to insecticides, gasoline, oil-base paints

A brass template, produced by a computerized numerical control (CNC) milling machine, was used as a pattern to form the front step and parabolic surfaces. In order to strengthen the reflector for mounting purposes, reinforcing aluminum assemblies were incorporated; a mounting plate was

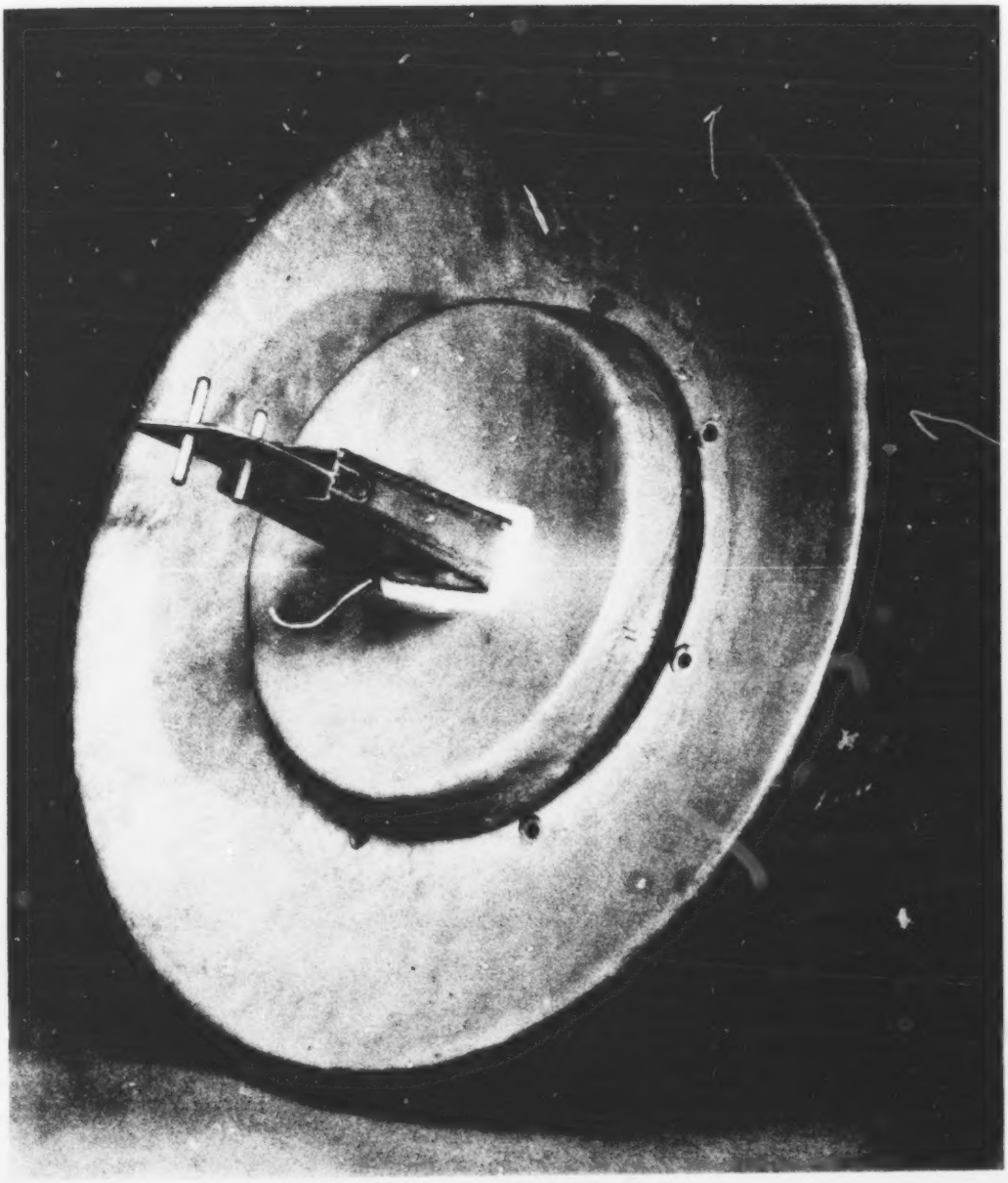


Figure 2 Antenna front view showing waveguide feed detail

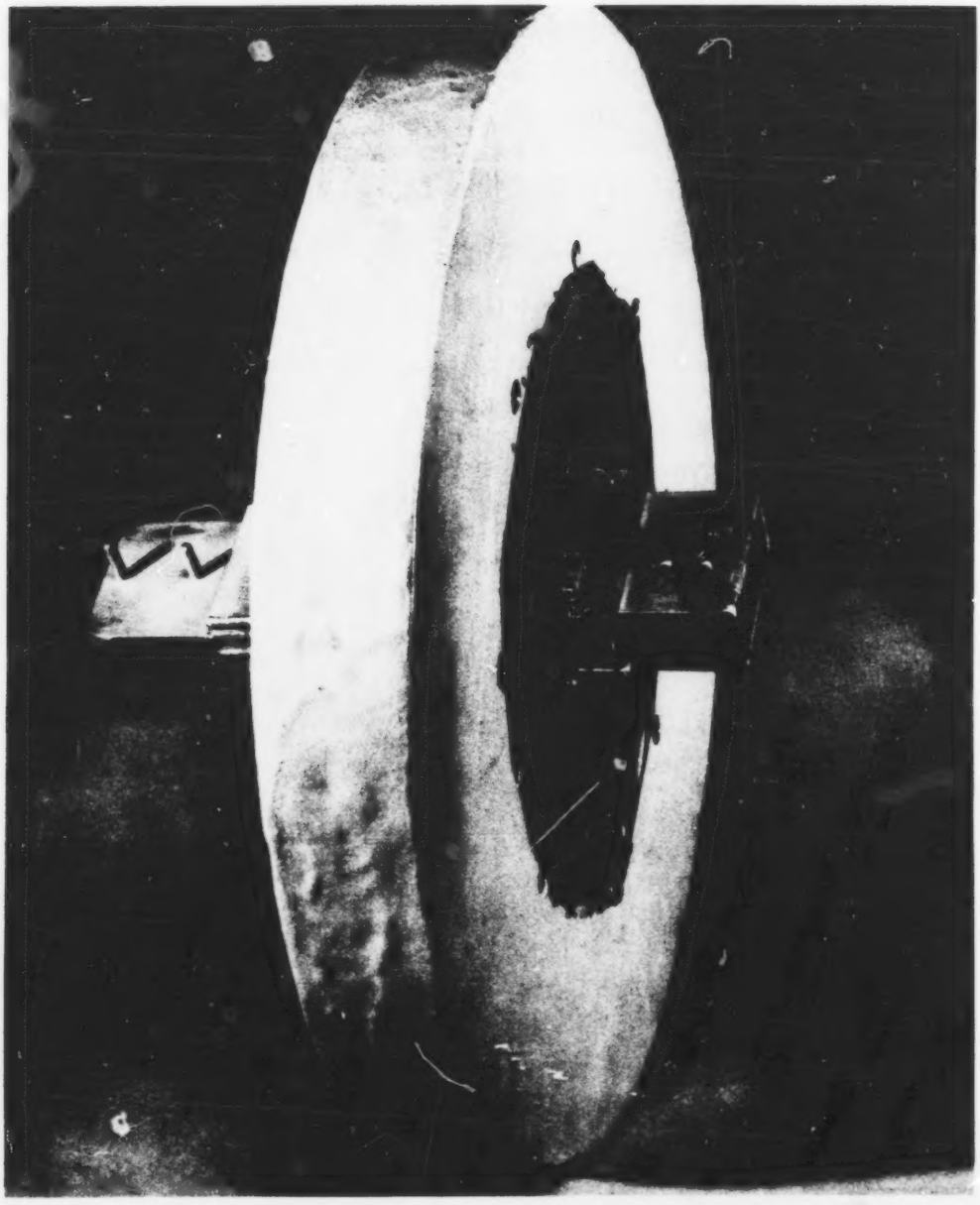


Figure 3 Antenna side view showing waveguide clamping arrangement

attached to the back surface with contact cement, and a hold down ring with corresponding mounting holes was embedded in the foam at the base of the front step.

After front surface machining was complete, two coats of latex paint were sprayed on to seal the foam and provide a bondable surface. Aluminum foil was then affixed with Weldbond adhesive. A coat of polyester resin was applied to the dish, then a layer of fibreglass cloth, followed by a second coat of resin. After a suitable curing interval, two final coats of polyester colour paste gave the finished dishes an aquamarine colour.

Reflector design drawings are presented in Figs. 4 to 7. Actual dimensions of the completed dishes slightly exceeded those shown on the shop drawings after fibreglassing was completed.

Feeds

Two identical double-dipole vertex aluminum feeds were built up on waveguide terminations for use at a wavelength of 10 cm. The two 0.25-in. (0.66-cm) diameter dipoles were mounted on a 0.125-in. (0.32-cm) web so that their axes lay on the plane of symmetry of the guide; Fig. 8 shows the feed detail including driven and parasitic element dimensions. The assemblies were carefully welded to prevent any excess material at the base of the dipoles or at the seams between the web and the waveguide (4).

An appropriate length of open waveguide was left to facilitate coaxial probe installation and impedance matching.

Aluminum clamps to hold the feeds in place were machined and fastened to the reflector aluminum backplate.

MEASUREMENTS

Tests of each antenna were completed in the following sequence:

1. initial focussing
2. impedance matching
3. final focussing and patterns
4. isolation

All radiation measurements were carried out using the 30-ft (9.1-m) short range on the roof of the Division of Electrical Engineering

building (5). A block diagram of the range and equipment is presented in Fig. 9a.

Impedance measurements were performed with a network analyzer system (6); see Fig. 9b.

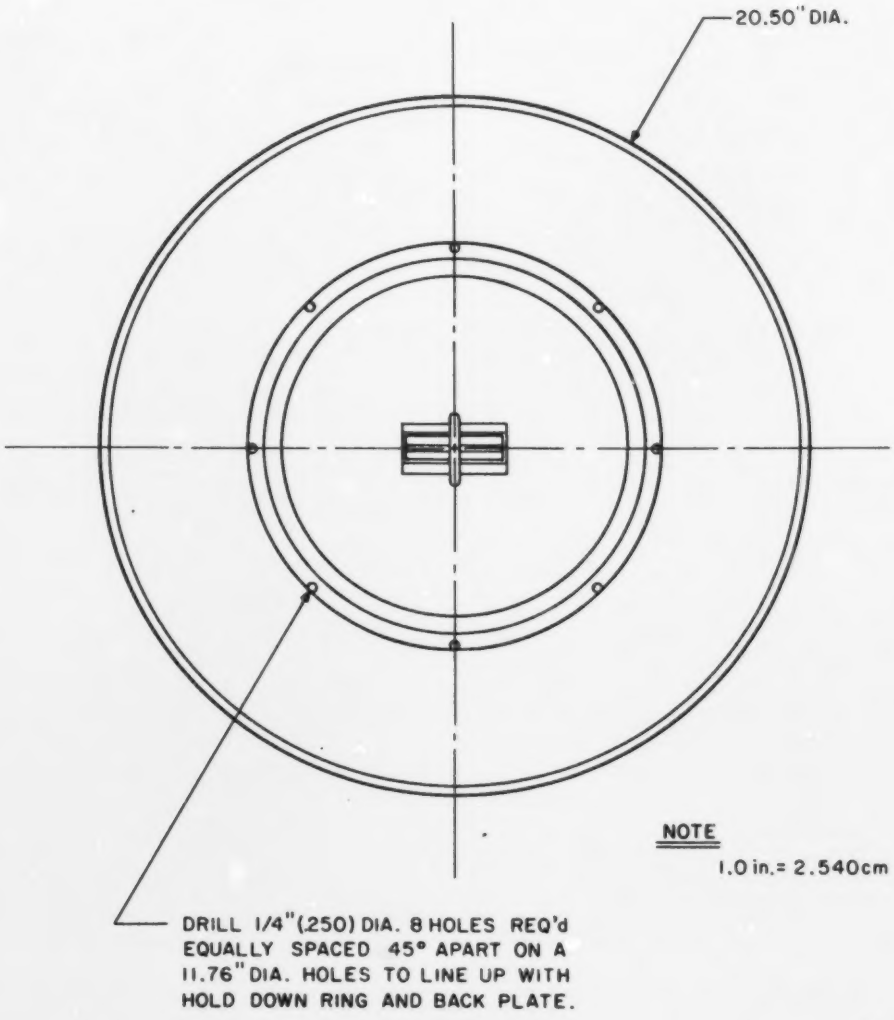

20.50" DIA.
NOTE
1.0 in.= 2.540cm
DRILL 1/4"(250) DIA. 8 HOLES REQ'd EQUALLY SPACED 45° APART ON A 11.76" DIA. HOLES TO LINE UP WITH HOLD DOWN RING AND BACK PLATE.

Figure 4 Construction drawing: front view

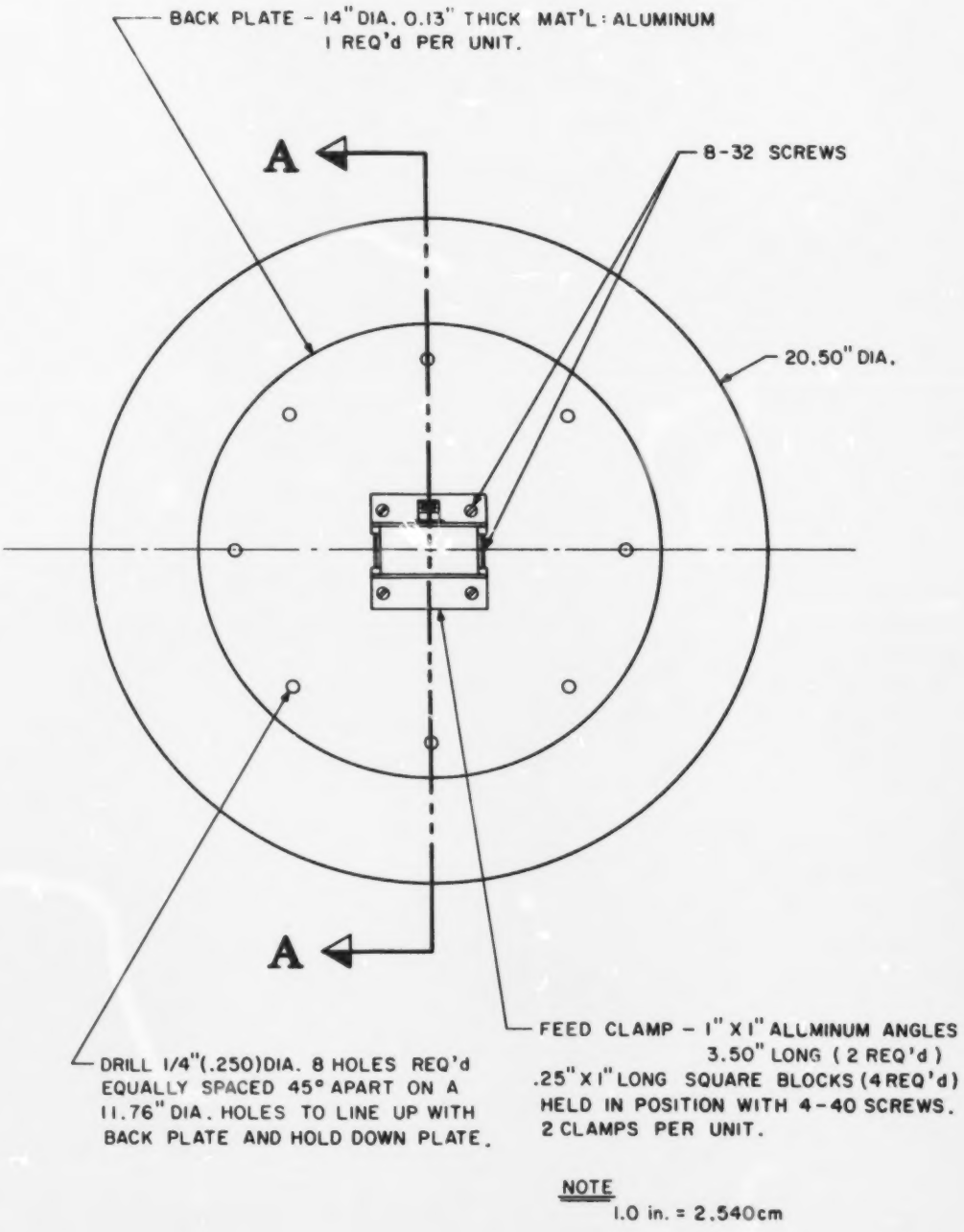
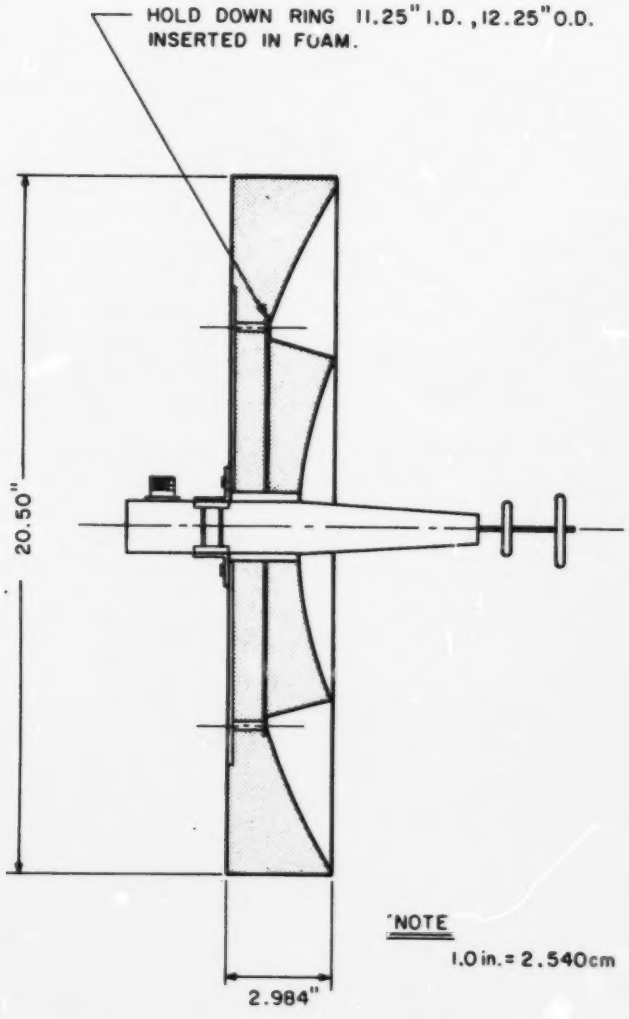
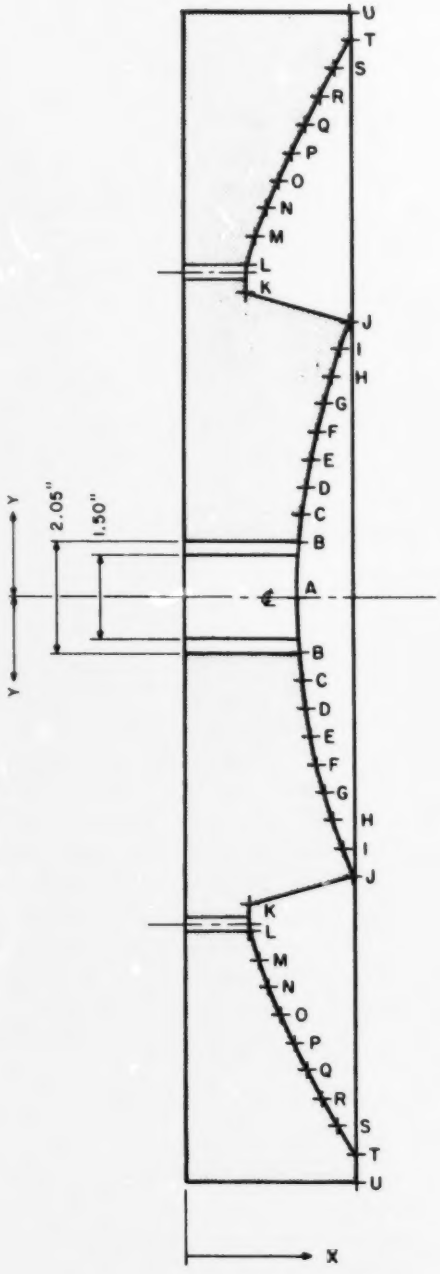

BACK PLATE - 14" DIA. 0.13" THICK MAT'L: ALUMINUM
1 REQ'd PER UNIT.
A
8-32 SCREWS
20.50" DIA.
A
DRILL 1/4"(.250)DIA. 8 HOLES REQ'd
EQUALLY SPACED 45° APART ON A
11.76" DIA. HOLES TO LINE UP WITH
BACK PLATE AND HOLD DOWN PLATE.
FEED CLAMP - 1" X 1" ALUMINUM ANGLES
3.50" LONG (2 REQ'd)
.25" X 1" LONG SQUARE BLOCKS (4 REQ'd)
HELD IN POSITION WITH 4-40 SCREWS.
2 CLAMPS PER UNIT.
NOTE
1.0 in. = 2.540cm

Figure 5 Construction drawing: back view



SECTION **AA**

Figure 6 Construction drawing: Side view



SECTION **AA**

PARABOLIC SURFACE DIMENSIONS

	X(in.)	Y(in.)
A	2.0	0
B	2.038	1
C	2.087	1.5
D	2.154	2
E	2.240	2.5
F	2.346	3
G	2.471	3.5
H	2.615	4
I	2.779	4.5
J	2.962	5
K	1.126	5.5
L	1.126	6
M	1.279	6.5
N	1.479	7
O	1.693	7.5
P	1.921	8
Q	2.165	8.5
R	2.423	9
S	2.696	9.5
T	2.984	10
U	2.984	10.25

NOTES

X = THICKNESS
Y = RADIUS
1.0 in. = 2.540cm

Figure 7 Construction drawing: parabolic surface detail

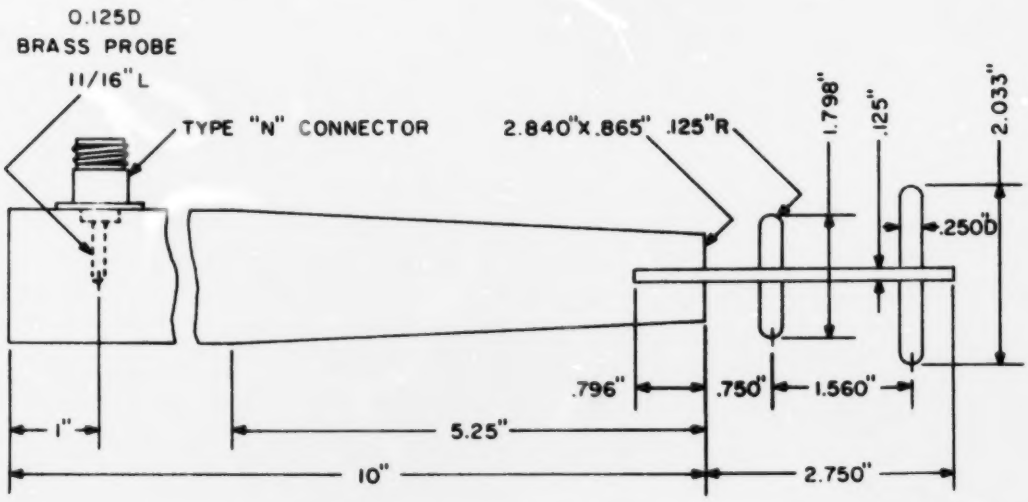


Figure 8 Waveguide feed detail (1 in. = 2.54 cm)

Initial Focussing

It was essential to determine the approximate feed position which would result in antenna characteristics of narrowest beamwidth, lowest side lobes, and best symmetry. Adjustments were begun using antenna 1 and a butt-jointed coax-waveguide adapter clamped to the open end of the waveguide feed. This enabled received signal to be fed by coaxial cable to a receiver, without having to weld a flange to the waveguide. A number of graduations were marked on the waveguide and the feed was moved in 0.125-in. (0.32 cm) increments until optimum focus was attained. The final position left ample waveguide length for placement of the coaxial feed probe without interference from the backplate clamping arrangement. This procedure was completed for each antenna in both the E and H planes. Final distance from the dish centre surface to the driven dipole was about 6 in. (15 cm).

Impedance Matching

The next step involved coaxially feeding and matching the antenna to free space so that maximum efficiency would be realized. Another requirement involved keeping the length of guide which extended behind the dish to a minimum.

A standard, female Type N, flange mounted panel receptacle (UG58A), with a small brass probe, was installed in the centre of one of the broad sides of the guide, close to the mounting clamps but leaving a

quarter to half wavelength for sliding short-circuit plunger adjustment. The brass probe diameter and length were varied until an acceptable match - with corresponding short-circuit adjustment - was attained. The sliding

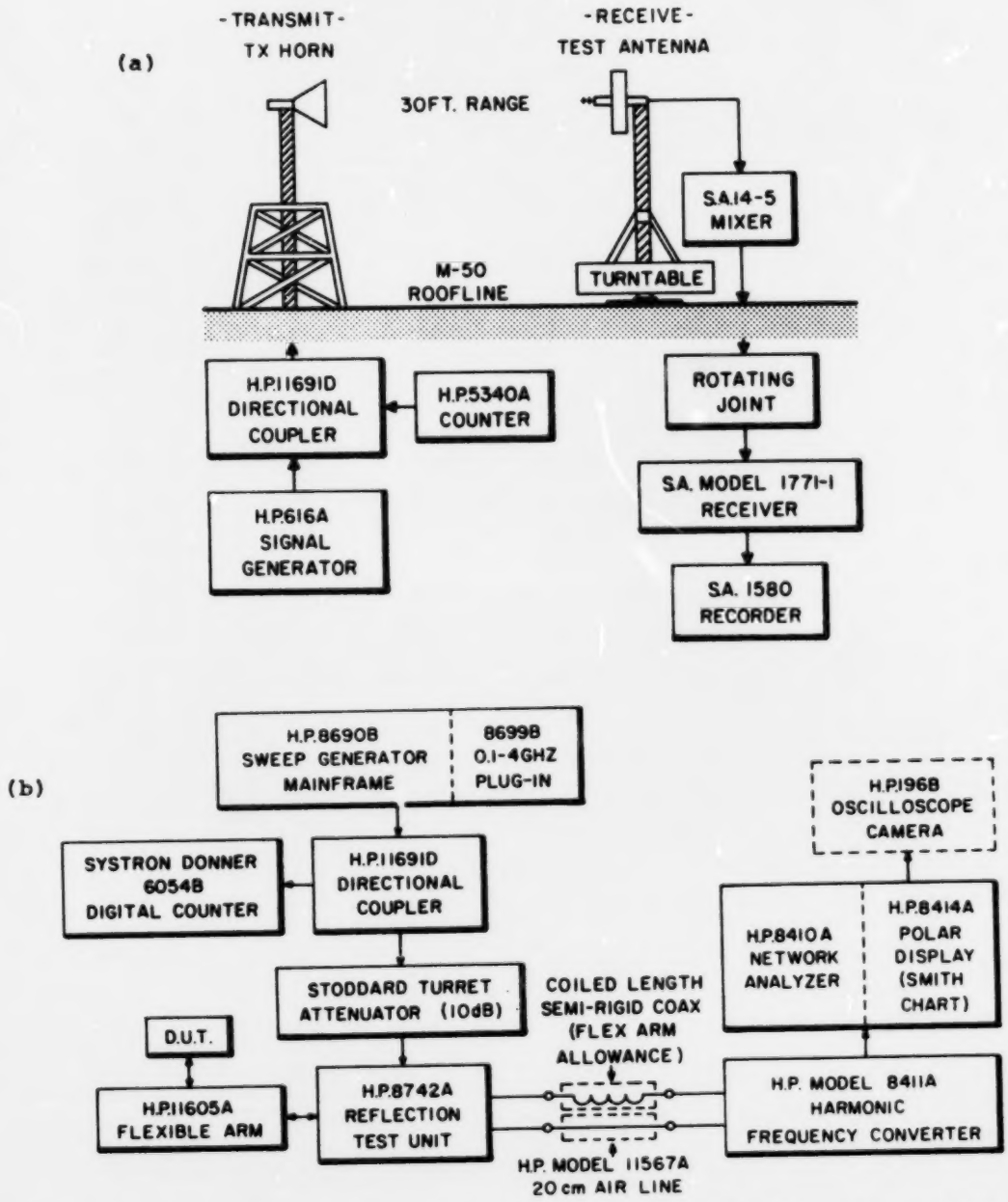


Figure 9 (a) Rooftop antenna pattern range. (b) Network analyzer block diagram

short-circuit plunger was then removed and replaced with a welded aluminum shorting plate. The final probe was approximately 0.125 in. (0.32 cm) in diameter and 0.675 in. (0.16 cm) in length; the short-circuit plate was about 1 in. (2.5 cm) from the probe.

Smith chart plots showing the final match for each antenna are shown in Fig. 10 a and b.

NORMAL
SCALE
VSWR MAX = ∞

FREQUENCY MARKERS IN GHz

EXPANDED
SCALE
VSWR MAX = 1.5:1

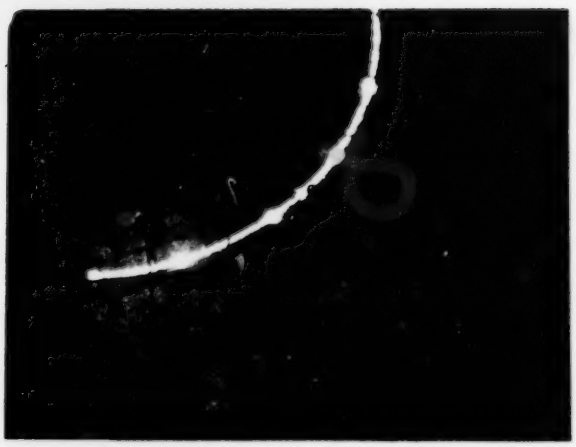
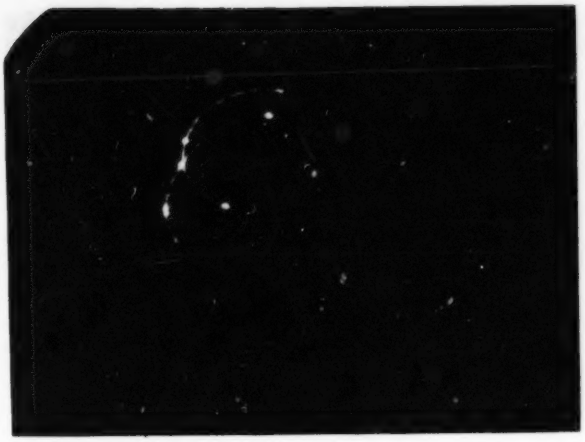


Figure 10a Impedance, Antenna #1



NORMAL
SCALE
VSWR MAX = ∞

FREQUENCY MARKERS IN GHz

EXPANDED
SCALE
VSWR MAX = 1.5:1

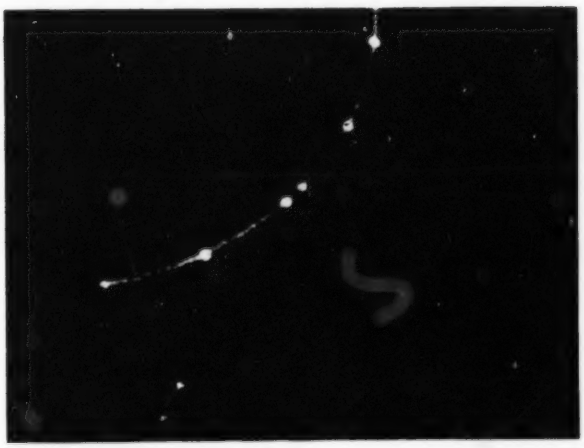


Figure 10b Impedance, Antenna #2

Final Focussing and Patterns

The matching feeds were locked in focus position, and a bead of silicon rubber sealant was applied to the front surface ports where the guides passed through the reflectors. Final E- and H-plane measurements at 3.0 GHz were recorded to confirm the performance of each antenna. Two kinds of rectangular plots were obtained: a normal ±180° azimuth sweep, and an expanded ±45° sweep of the main beam (see Appendix A). Significant parameters are given in Table 1.

Table 1. Radiation pattern characteristics

Plane	Antenna	First sidelobe level (dB)	3 dB beamwidth (deg)
H	1	15.2	12.8
	2	15.8	12.8
E	1	17.2	12.0
	2	17.3	12.1

Isolation

During survey work, the two antennas will be mounted about 14 ft. (4.3 m) apart either side of a helicopter fuselage. One antenna will be transmitting the pulsed signal toward the ground while the second unit will receive the reflected energy. For such application, about 80 dB isolation is needed between the two antennas.

An attempt was made to determine the isolation with the two antennas mounted about 5 ft. (1.5 m) apart and pointing into free space. The resulting 40 dB isolation was increased to 60 dB when a large sheet of metal was placed vertically between the two antennas.

Final techniques to achieve satisfactory isolation will take place after helicopter installation.

ACKNOWLEDGEMENTS

Three members of the staff of the Model Shop, Division of Electrical Engineering, made significant contributions toward the fabrication of the antennas; Mr. Gordon Moore was responsible for the machining and

fibreglassing of the reflectors; in connection with the waveguide feeds, Mr. David Marchington carried out machine work and Mr. Dalton Poulin completed the aluminum welding.

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APPENDIX I

Radiation Patterns

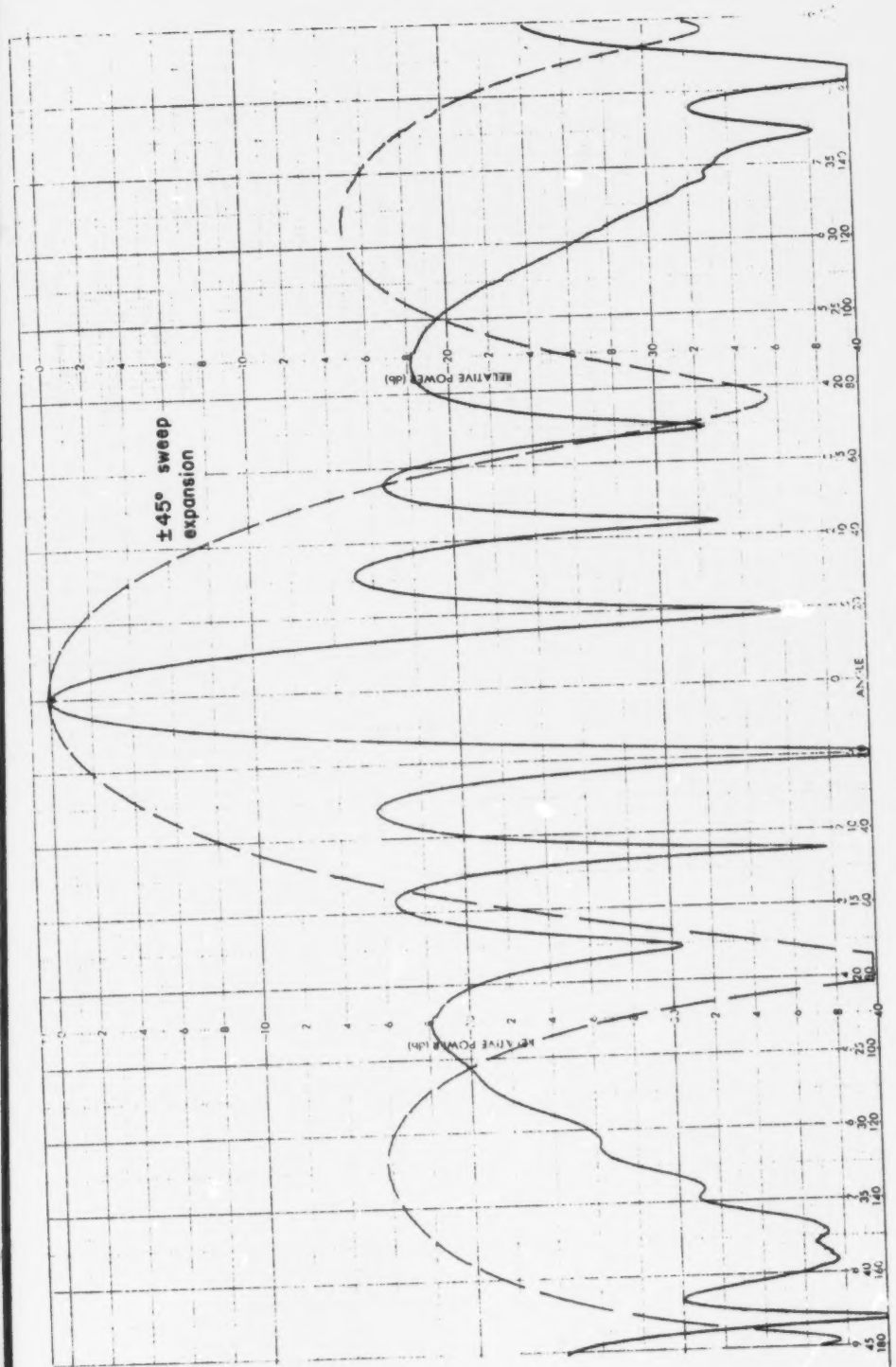

Figure A1 [illegible]. Radars Limited stepped parabolic antenna #1: H - plane, 3.0 GHz

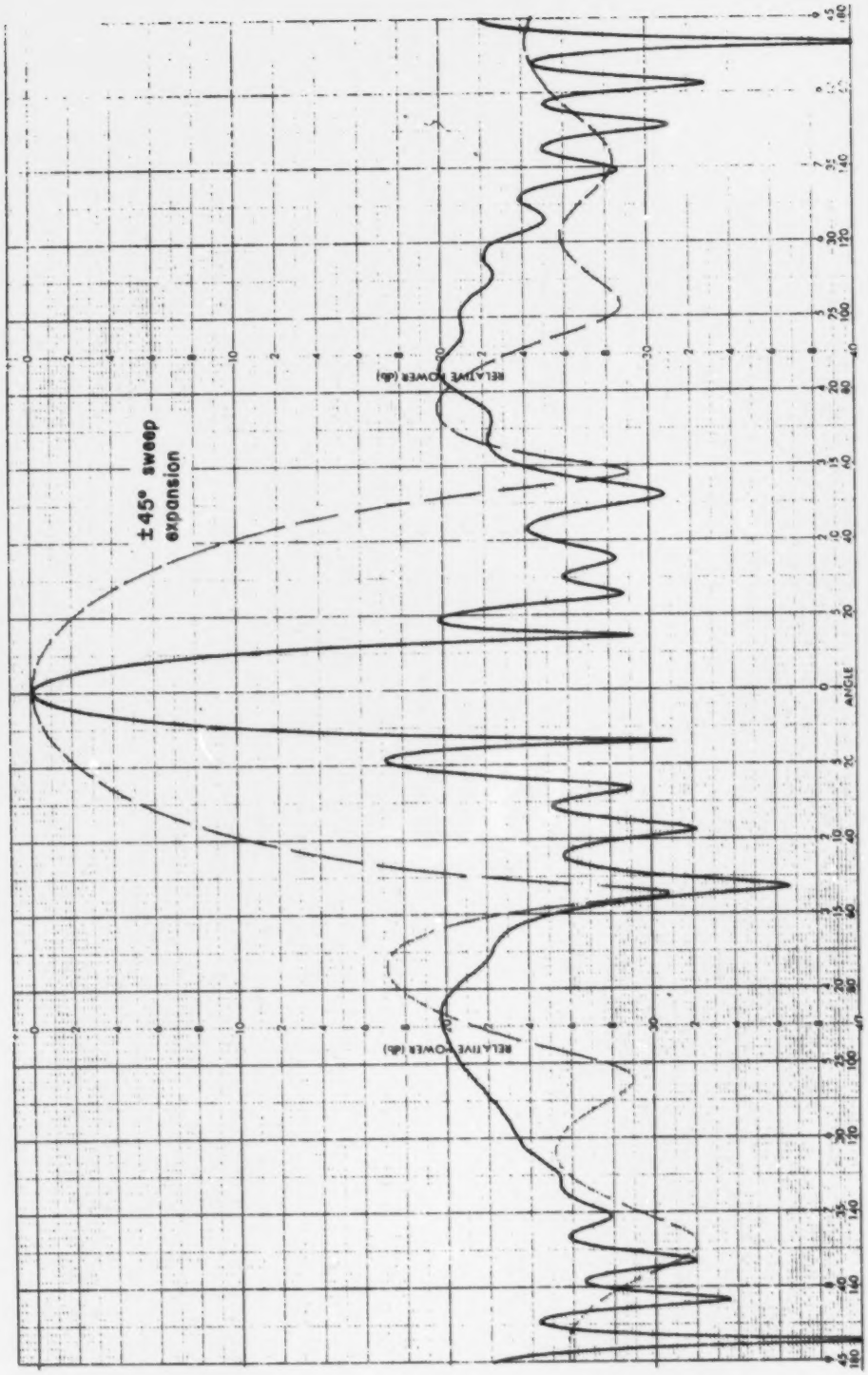

Figure A2 F.P. Radars Limited stepped parabolic antenna #1: E - plane, 3.0 GHz

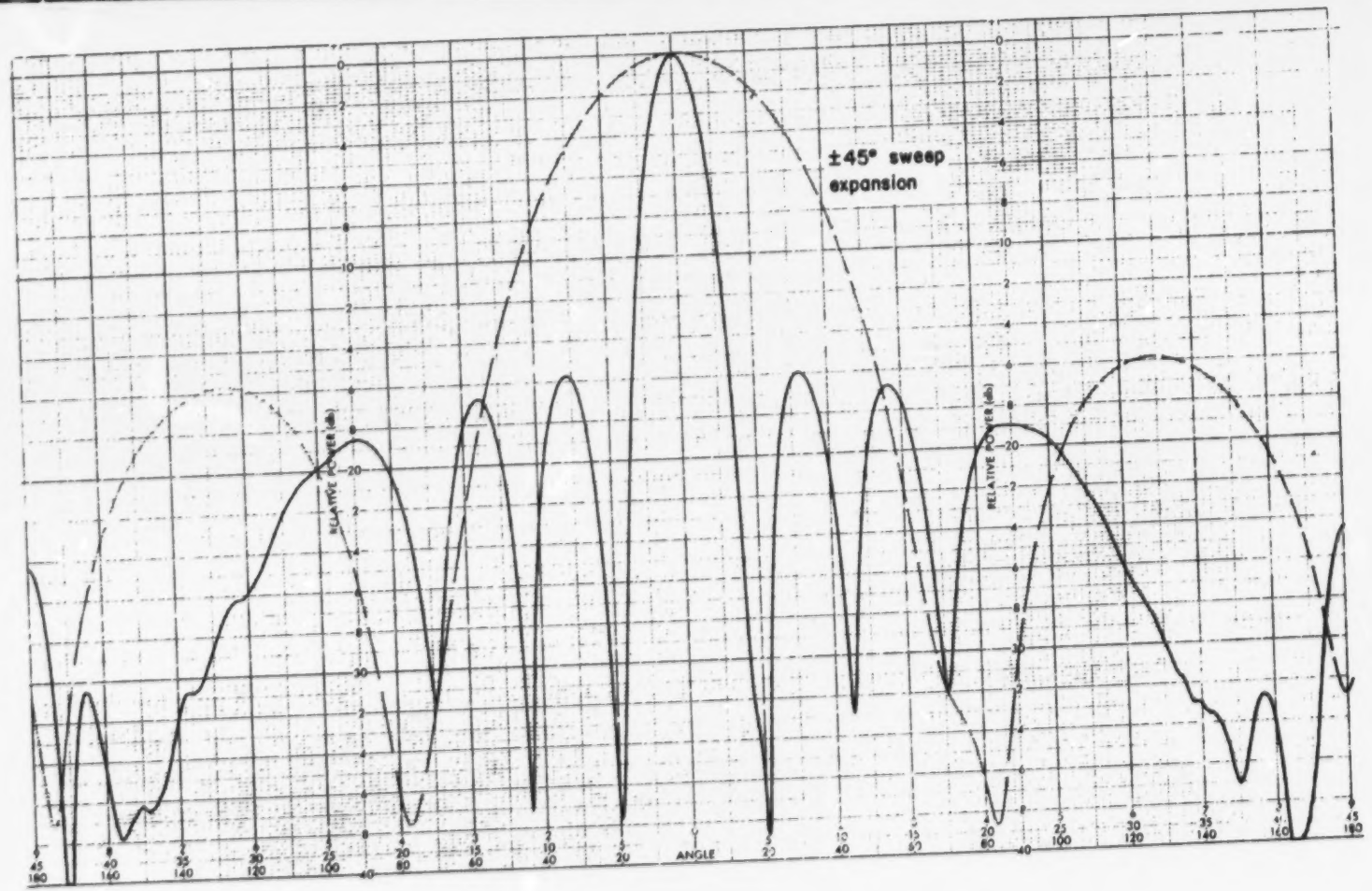

Figure A3 F.P. Radars Limited stepped parabolic antenna #2: H - plane, 3.0 GHz

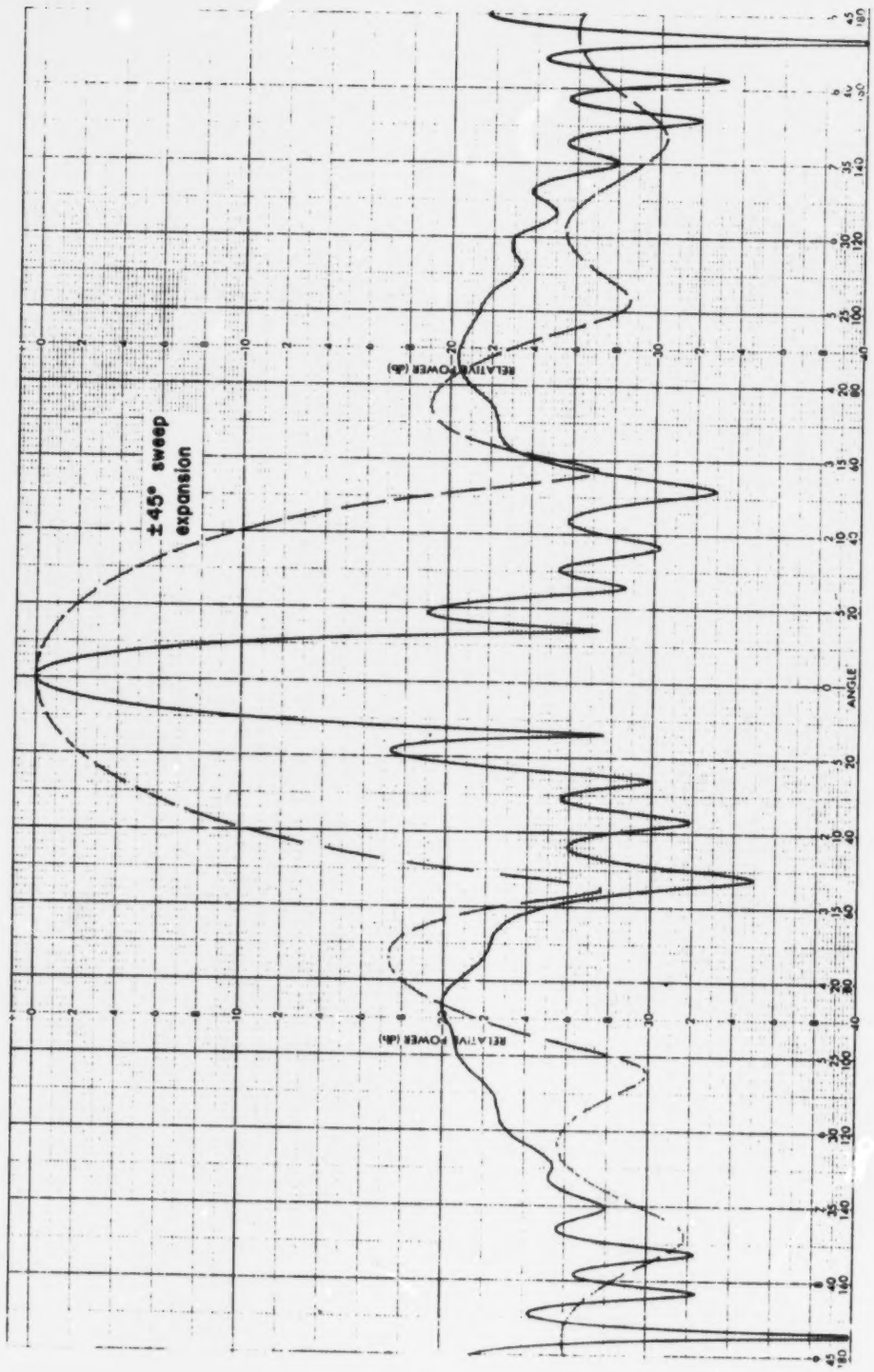

Figure A4 F.P. Radars Limited stepped parabolic antenna #2: E - plane, 3.0 GHz